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NOTE: ca 1980

TO: Larry Jensen, Reg. 5, Chicago

FROM: Jack Russell (ANR-460)

RE: External Exposure Rates from Thorium and Uranium  
in Soil

This is in response to our recent conversations concerning the NRC Interim Criteria for Cleanup of Radiation Contaminated Soil at Erwin, Tennessee. These criteria are also proposed by NRC for use at sites in West Chicago and St. Louis. A copy of the NRC interim criteria is attached. I gave you a preliminary opinion that the criteria appeared reasonable for uranium and plutonium cleanup. However, I recommend consideration be given to reducing the criteria for thorium. This memo provides further evaluation of these interim criteria.

First, the soil concentration criteria for the inhalation pathway were reviewed using data from the Radiation Risk Estimates being developed for EPA by ORNL under IAG # EPA-78-D-X0231. These data are summarized in the attached table in a format comparable to Table 2. of the NRC interim criteria. The EPA values for uranium, plutonium, and thorium-230 soil concentrations are about one half the NRC values. The EPA values for thorium-228 and -232 soil concentrations are similar to the NRC values. The EPA value for radium-228 (a beta emitter) is about three times the NRC value.

The conclusion from this comparison is that the NRC numbers for the inhalation pathway appear reasonable, being in most cases within a factor of 2 of EPA numbers. It is pointed out, however, that Th-228 is the critical radionuclide for the inhalation pathway from thorium ores, tailings, etc. Thus, soil analyses for thorium contamination should include this radionuclide.

The external gamma must consider contributions from contamination below the top 1 cm of soil. Oakley's paper (ORP/SID 72-1) and NCRP Report #45 were used to estimate this pathway. The dose conversion factors from NCRP Report #45 are 13.9 mrad/yr per pCi U-238/g of soil and 21.6 mrad/yr per pCi Th-232/g of soil. All decay products are assumed to be in equilibrium for both series.

Based on these values the proposed cleanup standard for uranium mill tailings (5 pCi/g with no depth specified) will produce an external dose rate of about 70 mrad/yr at one meter above an infinite plane with soil contaminated to an infinite depth. Thorium contamination will produce slightly greater dose rates of 108 mrad/yr at 5 pCi/g thorium-232 with all decay products in equilibrium and contamination spread over an infinite plane to an infinite depth. Both of these values assume all decay products are present and in equilibrium with the parent. These values can be reduced by accounting for shielding and occupancy rates.

NOTE: ATTACHED TO THIS MEMO WAS AN ANALYSIS OF EXTERNAL DOSES AT ONE METER ABOVE AN INFINITE PLANE WHEN CONCENTRATIONS VARY WITH DEPTH, BASED ON A PAPER BY KEITH SCHIAGER FROM 1974 (AT THE CRCPD ANNUAL MEETING)

Schiager's paper had the following values for shielding by earth that is contaminated with radium-226:

top 5 cm of soil contributes 37% of total dose at 1 meter

next 10 cm of soil contributes 27% of total dose at 1 meter

everything below top 15 cm (6 inches) of soil contributes remainder, i.e., 36%

Thus, when the standard (40 CFR 192) was finally issued, the following estimate could be made for the external dose based on Schiager's shielding values:

$$\text{top 5 cm:} \quad (13.9 \frac{\text{mrad/yr}}{\text{pCi/g}}) (.37) (5 \text{ pCi/g}) = 25.7$$

$$\text{next 10 cm:} \quad (13.9 \frac{\text{mrad/yr}}{\text{pCi/g}}) (.27) (5 \text{ pCi/g}) = 18.7$$

$$\text{below 15 cm:} \quad (13.9 \frac{\text{mrad/yr}}{\text{pCi/g}}) (.36) (15 \text{ pCi/g}) = 75.1$$

$$\text{TOTAL} \quad = 119.5 \text{ mrad/yr}$$

(or 13.6 microrad/hr)

where the standard limits radium concentrations to 5 Ci/g in the top 15 cm layer of soil and 15 pCi/g in any 15 cm layer below the top 15 cm layer.

Since background radiation generally is considered as either 100 mrem/yr or 10 microR/hr, this standard allows a doubling of the natural background external radiation exposure rate.

Table Z. Radiation Concentrations Resulting in an Inhalation  
Dose of 10 mrem/yr

Radionuclide	Dose Conversion Factor (rem per microCurie inhaled)	Soil Surface Concentration (microCurie per sq. m)	Soil Concentration (pCi/g)
U-238	842	0.407	16.3
U-235	848	0.404	16.2
U-234	940	0.364	14.6
Th-232	850	0.403	16.1
Th-230	920	0.372	14.9
Th-228	1240	0.276	11.0
Ra-228	404	0.848	33.9
Pu-239	1020	0.336	13.4
Pu-238	1060	0.323	12.9

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Notes: A) dose conversion factors from Radiation Risk  
Estimates, IAG #EPA 78-D-X0231, with ORNL, for Y Class,  
AMAD = 1 micron  
B) resuspension =  $5 \times 10^{-9}$ /m  
C) soil = 2.5 g/cc